Chapter 12

Fire and Fuels Management in Relation to Owl Habitat in Forests of the Sierra Nevada and Southern California

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Over the millennia, fire has influenced the structure and function of most forested ecosystems and, consequently, most spotted owl habitat in California. Fire is a force that we must understand and attempt to deal with--as a shaper of ecosystems, as a tool, and as a potential destroyer of habitat-if we are to manage intelligently for the California spotted owl. In this chapter we discuss some fire management considerations related to protecting and possibly enhancing owl habitat. We concentrate on Sierran mixed-conifer forests--the most important and extensive habitat type statewide for the spotted owl, and on live oak/bigcone Douglas-fir forests--one of the most important habitat types in southern California (table 1B). We include brief discussions of three additional types-Sierran red fir and southern California mixed-conifer and riparian/hardwood.

Sierran Mixed-Conifer

Sierran mixed-conifer forests contain an estimated 62 percent of all California spotted owl sites in California (table 1B). They are characterized by mixtures of white fir, ponderosa pine, sugar pine, incense-cedar, black oak, Douglas-fir, and giant sequoia. The forest type occurs throughout middle elevations of the Sierra Nevada (Tappeiner 1980; table 1B).

An appreciation of the concept of fire regimes is helpful in understanding the role of fire in mixed-conifer forests. A fire regime is an expression of the frequency, severity, and extent of fires occurring in an area (Agee 1990). It is a function of the frequency with which fuels are dry and continuous enough to carry fire at a time when ignition sources are available, and thus is strongly related to climate. In general, the longer the fire-free interval, the more severe the fire that follows, because more fuels have accumulated in the interim.

Prior to European settlement in the mid-1800s, Sierran mixed-conifer forests were characterized by a short-interval, low- to moderate-severity fire regime. As a result of human activities since the mid-1800s (Chapter 11), including a policy of fire suppression initiated soon after the beginning of the twentieth century, this fire regime has been changed to one of less frequent but substantially more severe fires.

Presettlement Fire Regimes

Several studies have shown that mixed-conifer forests burned rather frequently during the centuries preceding European settlement. Lightning and, in many areas, Native Americans provided the ignition sources. The most comprehensive body of work on fire history in the Sierra Nevada has been done in the giant sequoia groves (Swetnam et al. 1991, Swetnam pers. comm.). These studies documented fire occurrence for 1,500 years and indicated a mean fire interval of 5 to 10 years since 1300 AD for the five groves studied. Maximum fire intervals recorded were 20 years. Other studies (Kotok 1933, Wagener 1961, Kilgore and Taylor 1979, Warner 1980, Skinner 1991) suggested that the mixed-conifer type had a mean fire interval in the range of 5 to 30 years. Mean fire intervals varied in response to site and environmental factors that affected ignition source, fuel accumulation, fuel moisture, and burning conditions. Thus, more mesic sites (for example, moist canyon bottoms, northerly slopes, and higher elevations) and sites protected from winds burned less often than relatively xeric and/or exposed sites (Kilgore and Taylor 1979, Teensma 1987). (The relatively mesic sites may tend to be more closely associated with nesting and roosting habitat used by the spotted owl.) Furthermore, climatic fluctuations on a time scale of centuries (fig. 11X) were reflected in more frequent fires during drier periods (Swetnam et al. 1991).

Frequent fires in the mixed-conifer type maintained surface fuels at fairly low levels, and kept understories relatively free of trees and other vegetation that could form fuel ladders to carry surface fires into the main canopy. This effect of frequent fires, together with widespread, heavy grazing by sheep after the mid-1800s (Chapter I1), probably accounts for the common reports by early observers that forests of the Sierra Nevada were open and parklike (Sudworth 1900, Biswell 1989). Because fuel accumulation was limited, most fires were of low to moderate severity (Sudworth 1900, Kilgore 1973, Biswell 1989). High-severity crown fires usually could not be sustained over large areas (Show and Kotok 1924, Kilgore 1973, Kilgore and Taylor 1979). On the other hand, crown fires that affected small areas .(ranging in size from a single tree, to groups of trees, to perhaps several acres) probably were relatively common and an important influence on stand structure. These patches of high fire severity, interspersed within a "matrix" of low-severity fires (Stephenson et al. 1991), occurred in areas with heavy fuel accumulations, sometimes reinforced by steep slopes or extreme weather conditions. This complex fire regime, along with other agents of disturbance (for example, group kills of trees by bark beetles), produced a variable, irregular patchwork of even-aged groups, most from less than an acre to several acres in size (Show and Kotok 1924; Rundel et al. 1977; Bonnicksen and Stone 1981, 1982; Biswell 1989). Consequently, a relatively fine-grained pattern of variability, modified by topography, existed at a landscape scale.

Openings created by fires and other disturbances provided conditions favorable for regeneration and growth of shade-intolerant and relatively fire-resistant trees and other plants. These species include ponderosa pine, giant sequoia, and California black oak, which is only moderately resistant to top-kill by fire but sprouts vigorously. They were able to regenerate successfully in the presence of frequent fires because of the fuel dynamics of openings in which they became established: A typical scenario may have begun with the death of a small group of trees-by bark beetles, locally-intense fire, or other causes. The resulting concentration of fuel was reduced by one or more fires. Mineral soil was exposed, and competing vegetation (including reserves of dormant seeds stored in duff and soil) was reduced. Given a good cone crop and favorable soil moisture and other conditions, seedlings became established. Subsequent fires in the vicinity burned only lightly, if at all, through the opening because of the local lack of an overstory to provide sufficient litter to carry the fire. By the time the new regeneration produced enough litter to carry a fire of appreciable intensity through the opening, some of the young trees were large enough to survive the fire (Kilgore 1973, Biswell 1989). Fire-resistant species would have comprised a disproportionate number of the survivors.

The more shade-tolerant and fire-sensitive species (white fir and incense-cedar) regenerated beneath overstory trees as well as in openings. Periodic fires, however, kept their numbers relatively low, especially in the understory. The more mesic sites generally experienced longer fire intervals and thus permitted more individuals of fire-sensitive species to survive and grow (Kilgore and Taylor 1979).

Twentieth Century Fire Regimes

Twentieth century fire regimes bear little resemblance to those of presettlement times, largely because of human activities since the mid-1800s. One marked difference has been in the annual acreage burned. For example, using a conservative mean fire interval of 20 years for the 586,000-acre Eldorado National Forest (NF), we would expect a mean of 29,000 acres to burn annually. In fact, 13,944 acres burned during the entire period from 1970 through 1990-an average of only 664 acres per year. On the 1,168,500-acre Plumas NF, 85,000 acres burned in the same 21-year period-an average of 4,048 acres per year, although about 58,000 acres would be expected to burn there each year with a mean fire interval of 20 years.

We must get beyond the number of ignitions and acres burned, however, to evaluate relations of wildfires to spotted owl habitat. A study of lightning fires by vegetation type in Yosemite National Park (NP) showed that over 50 percent of the 2,000 fires ignited between 1930 and 1983 occurred in the mixed-conifer zone (van Wagtendonk 1986). Forest Service statistics do not categorize fires according to vegetation types. Most NFs, however, do have maps that can provide useful information about the spatial and temporal distribution of fires during the twentieth century. Figures 12A and 12B, for example, show the distribution of all lightning fires and all large fires (100+ acres) on the Lassen NF since 1900. Lightning-caused ignitions were scattered over the entire forest. Fires that escaped initial attack and grew large, however, were not evenly distributed. Large fires were grouped in Sierran foothill areas and on the east side of the crest. Similar patterns occurred farther south in the Sierra Nevada. In the 1920s and 1930s, many fires occurred in Sierran foothills and at lower elevations in the mixed-conifer belt-the same general areas where early timber operations (Chapter 11) and widespread burning for range improvement were concentrated. Fires east of the Sierran crest accounted for much of the balance of the large fires this century. Over 50 percent of the nearly 85,000 acres of forested land burned on the Plumas NF since 1970, for example, have burned east of the crest. Within these two broad zones that dominate forest fire statistics in the Sierra Nevada, owls use significant portions of the lower-elevation forests on the western slopes, at least down through the ponderosa pine/hardwood type to the upper digger pine/blue oak type, but they are rare in the eastside forests. In these two zones, fires more often move rapidly beyond the initiating stage and defy initial attack because of flashy fuels, drier conditions, and exposure to high winds.

By comparison, success of initial attack on wildfires evidently is greater in areas of owl habitat within the Sierran mixed-conifer type. Countryman's (1955) description of fuel conditions within old-growth stands applies in large measure to fuel conditions within many mixed-conifer stands used by the California spotted owl. These stands are less flammable under most conditions, because the dense canopies maintain higher relative humidities within the stands and reduce heating and drying of surface fuels by solar radiation and wind. The reduction of wind velocity within closed stands discussed by Countryman is supported by wind reduction factors identified by Rothermel (1983) for stands with closed canopies. Windspeed at mid-flame height for fires burning in surface fuels is approximately one-tenth of the windspeed 20 feet above the stand canopy.

As fuels accumulate, however, fires that do escape initial attack -usually those burning under severe conditions-are increasingly likely to become large and damaging. Success in excluding fire from large areas that were once regulated by frequent, low- to moderate-severity fires has simply shifted the fire regime to one of long-interval, high-severity, stand-replacing fires (van Wagtendonk 1974, Kilgore 1973, Parsons and DeBenedetti 1979, Agee and Edmonds 1992). Forests where owls are found more often than expected (Chapter 5) satisfy the structural requirements outlined by Rothermel (1991) for the propagation and spread of crown fires-heavy accumulations of dead-and-downed fuels, conifer reproduction and other ladder fuels, and continuous forests of conifer trees. Crown fires occur when these features are combined with dry fuels, low humidities, high temperatures, steep slopes, strong winds, and unstable atmosphere.

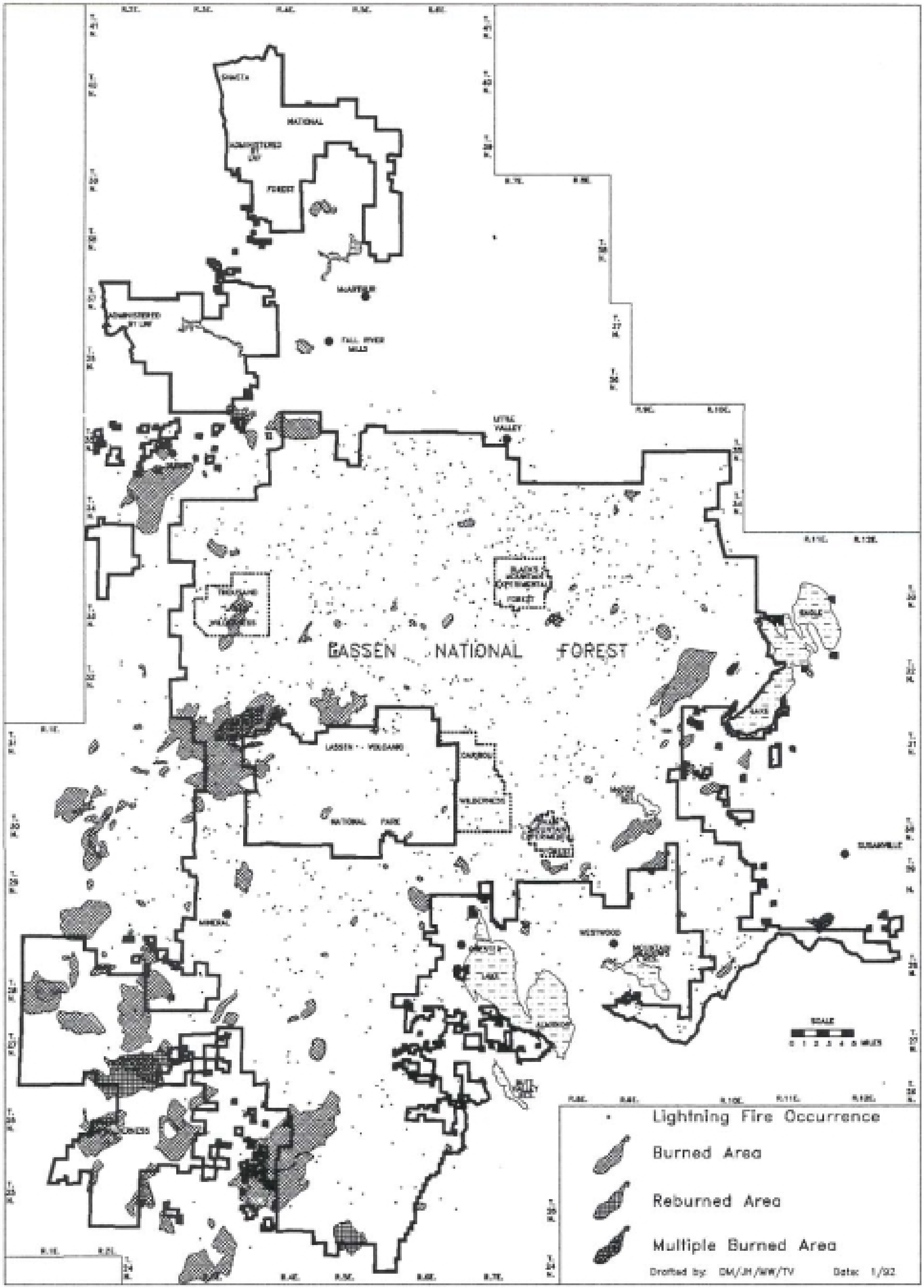

Figure 12A--Fire history of the Lassen National Forest from 1900 through 1939.

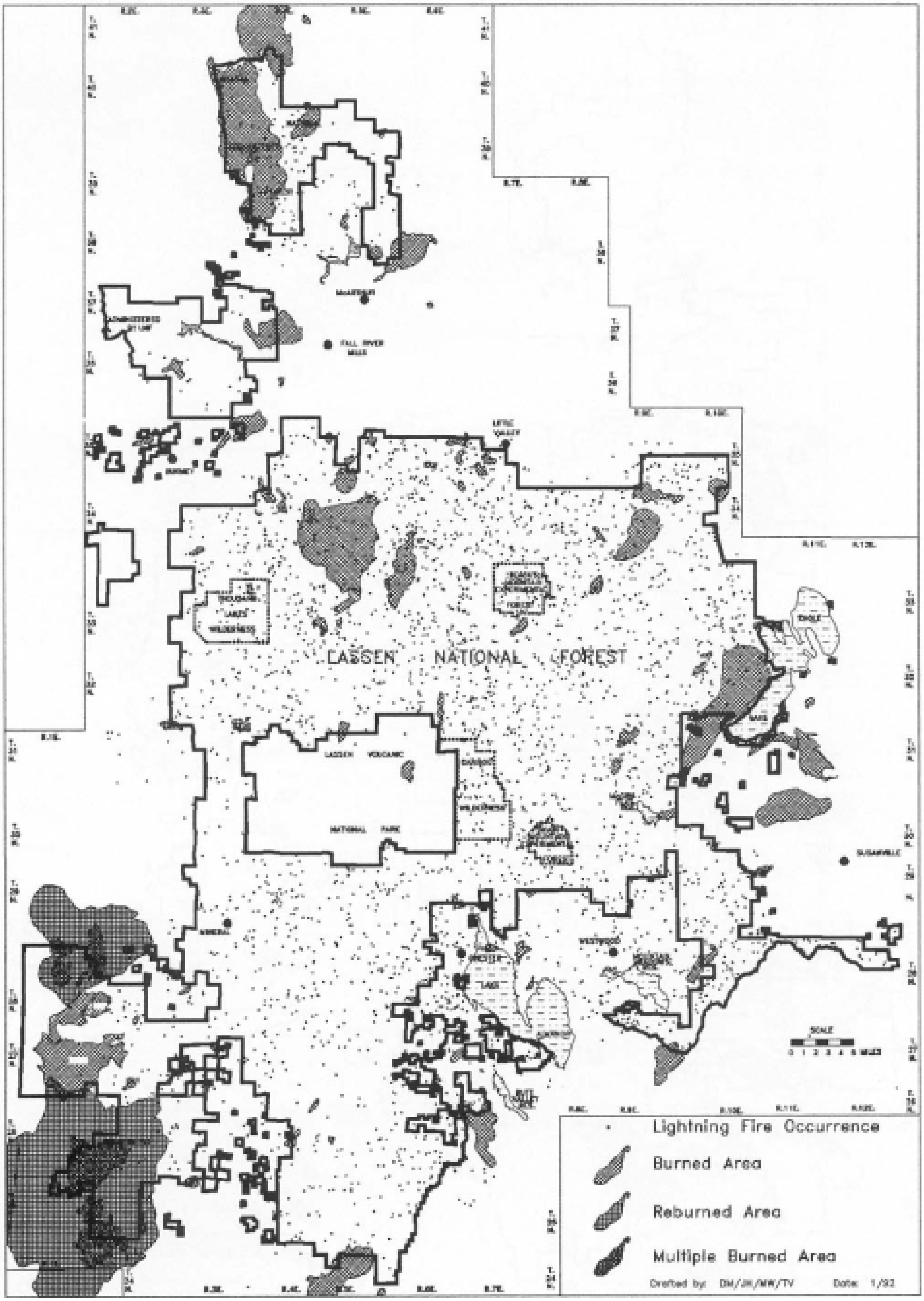

Figure 12B--Fire history of the Lassen National Forest from 1940 through 1990.

Two recent examples of severe, stand-replacing wildfires in owl habitat in the mixed-conifer type were the Stanislaus Complex (1987) on the Stanislaus NF and the Stormy Fire (1990) on the Sequoia NF. Both of these fires burned areas with known owl sites. Numerous other large fires have burned in the general elevational band where owl habitat is found. Although these areas had not been surveyed for owls prior to burning, we assert that they were also home to owls prior to fire. Based on such fires, we suggest three scenarios for severe wildfires in Sierran or southern California mixed-conifer types:

Scenario l: A fire initiates low on the slope, typically in brushfields, and spreads into the mixed-conifer zone. The fire does not drop to the forest floor because heavy fuel accumulations and fuel ladders, combined with steep slopes, promote either spread through crowns or widespread torching of trees. This is the expected model for areas of mixed-conifer forest lying directly upslope from large brushfields and for imbedded habitat in brushfields in southern California forests. Such fires bum for one to several burning periods (see glossary). Fire behavior is controlled by topography and fuels. Generally the fire is contained within one or several drainages. Control lines are constructed at the break in slope. Regular occurrence of this type of fire results in gradual loss of habitat.

Scenario 2: Many lightning fires are ignited simultaneously and fire-fighting resources are quickly exhausted. All resources are devoted to initial attack or to protection of structures and communities threatened by fires that escape initial attack. Fires become large and burn under changing weather and fuel conditions, until enough resources can be gathered and organized to effect control. In such cases fires burning in uniform fuels become so large that suppression remains unsuccessful until weather conditions moderate, spread ceases, and firelines can be constructed around the entire perimeter. Groups of lightning fires in 1977 and 1987 were examples of this scenario. Weatherspoon and Skinner (1992) found that the effects of such unconstrained fires depended on the fuel conditions they burned through, and corresponded well with prior management actions, including fuel treatments.

Scenario 3: A human-caused fire starts under severe fire weather conditions. Fire spread continues through the duration of the wind event. Examples of synoptic weather patterns associated with such events are detailed by Schroeder et al. (1964). Examples are east winds in the northern Sierra Nevada and Santa Ana conditions in southern California.

A study of lightning fires and spotted owl territories in Yosemite NP showed that owls can and do exist with extensive fires of varying intensities where forest structure has been affected relatively little by human activities. Fifty-six owl sites were confirmed in the Park during surveys in 1988 and 1989 (Gould pers. comm.), and an additional 45 locations were identified as probable owl sites in unsurveyed areas of the Park where the habitat appears to be suitable for the owls (Steger pers. comm.). Among the 56 confirmed sites, six had been burned by prescribed natural fires during the 8 years prior to the surveys when owls were located there (fig. 12C). Over 800 acres of habitat within a 1,200-foot radius of confirmed owl sites had been burned, and an additional 1,300 acres had been burned within a 2,000-foot radius. Crown fires were extensive in one case, although the nest site itself was under-burned. The remaining fires were primarily low to moderate in intensity, with only occasional torched areas.

Effects of Fire Suppression

The structure and composition of Sierran mixed-conifer forests have been affected profoundly by fire suppression policies begun in the early 1900s. This and other forest types with short-interval fire regimes have been changed more by suppression than types with longer fire intervals because more cycles of fire and associated fire effects have been excluded in the short-interval regimes.

As frequent fires of low to moderate severity ceased to be a dominant ecological force, shade-tolerant and fire-sensitive tree species (especially white fir) increased dramatically in abundance, particularly in small to medium size classes. Previously much less common except in the cool and moist extremes of the type, multiple-canopied stands consisting largely of these shade-tolerant species are now common (Parsons and DeBenedetti 1979, Bonnicksen and Stone 1982, van Wagtendonk 1985). Regeneration of pines, black oak, and other shade-intolerant species has declined, except in areas opened by wildfires or management activities. "Selective" cutting has reinforced the changes in stand structure and composition brought about by fire exclusion (color photo 5-10). The patchwork of small, even-aged aggregations that characterized the mixed-conifer type before 1900 has become less distinct (Bonnicksen and Stone 1982). Consequently, stands have become more complex when viewed vertically, but less complex and more homogeneous in terms of areal arrangement.

With fire suppression, fuels on the forest floor (including coarse woody debris) have accumulated far beyond their normal levels (Parsons and DeBenedetti 1979). The increased prevalence of white fir in the understory has created hazardous fuel ladders, linking surface fuels to upper canopy layers (color photos 5-5, 5-10, 5-12 to 5-14). Increases not only in quantity, but also in horizontal and vertical continuity, of fuels have substantially increased the probability of large-scale, catastrophic fires (Kilgore and Sando 1975, van Wagtendonk 1985).

Unnaturally dense stands mean more competition for available water, and therefore greater moisture stress. During periods of drought, notably the current one (fig. 4H), extensive mortality is the result-some directly from drought stress, much from stress-induced bark beetle outbreaks. These stands may be more prone to damage from defoliating insects and various root and stem diseases as well. The dead and dying trees also add greatly to the already high fuel loads, thereby increasing intensity and rate of spread in the event of a wildfire. More snags and large woody fuels are likely to increase fire spotting and suppression difficulty, and greater heating damage to soils may result from consumption of more large materials. Moreover, opening of the canopy as a result of tree mortality permits more solar radiation and wind to reach the ground, resulting in warmer and drier fuels (Countryman 1955), which ignite more easily and support more intense, faster-spreading fires.

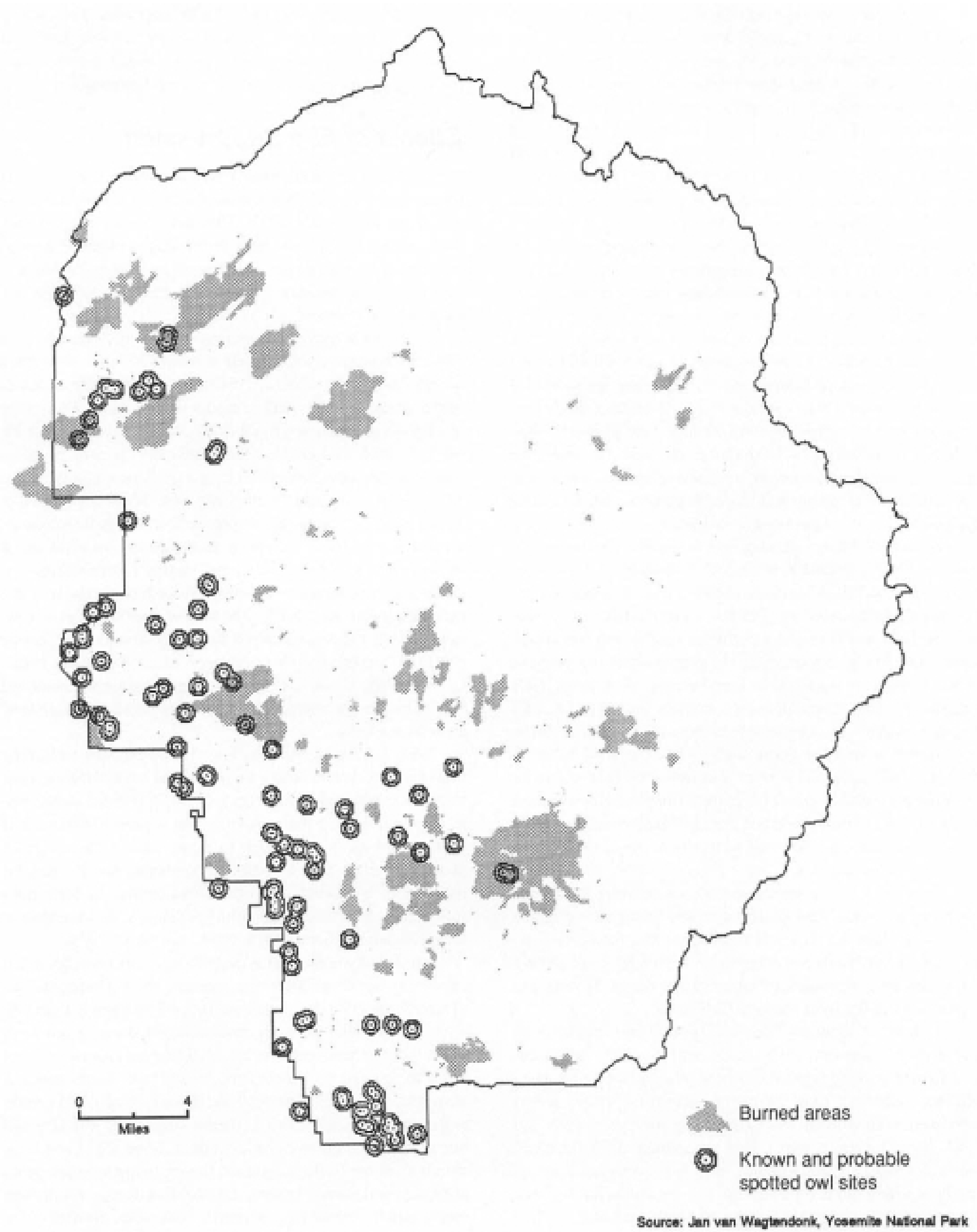

Figure 12C--Known and probable spotted owl sites and lightning fires in Yosemite National Park from 1930 through 1989 (based on data from Gould pers. comm., Steger pers. comm., and J. W. van Wagtendonk pers. observ.).

Implications for Spotted Owl Management

Several changes at least partly attributable to fire suppression (for example, increased stand density, greater development of middle and lower canopy layers, more snags, more coarse woody debris) have been associated with biologists' perceptions of suitable owl habitat. Other such changes may be detrimental to habitat quality. Excessively dense understories may impede foraging and, to the extent that diversity of tree species-to include pines and oaks-is important, continued exclusion of fire may be degrading habitat quality. Much uncertainty still clouds our understanding of which stand attributes are critical for owls and which are only incidental. Nevertheless, it is possible that fire exclusion in Sierran mixed-conifer forests has led to a net improvement in spotted owl habitat there.

If owl habitat has improved as a result of fire suppression, such improvement may well be illusory and short-lived. Fire is inevitable in these forests, and the probability of catastrophic fire-certainly one of the greatest threats to owl habitat-increases as surface fuels and ladder fuels continue to accumulate (Kilgore and Sando 1975, van Wagtendonk 1985). Overly dense stands are subject to extensive mortality from drought and insects, including loss of the most desirable large, old trees.

Another possibility is that owls were highly successful in presettlement stand structures resulting from the unimpeded functioning of natural processes, including fire. For Sierran mixed-conifer forests, such a landscape probably consisted of a complex array of mostly small, even-aged aggregations and/or stands representing a wide range of age- and size-classes. Compared with current stand structures, stands would have been less dense, and groups of different-sized trees would have been separated more horizontally into even-aged aggregations with less vertical diversity within groups.

In either case, a management policy characterized as "hands-off plus fire exclusion" (allow forest succession to proceed uninterrupted by periodic natural disturbances) would likely lead to degraded and depauperate, rather than healthy and biologically diverse, ecosystems. A more prudent and conservative policy for the spotted owl, as well as for other species and ecosystem components, would be to use our understanding of natural ecosystem processes (including fire) to guide management (see management options later in this chapter and in Chapter 13).

Fuels

Nesting and roosting areas in Sierran mixed-conifer forests exhibit structural characteristics (Chapter 5) that affect fire behavior. These stands have large trees, closed canopies, and multiple layers. Vertical and horizontal structures are continuous, encouraging the movement of fire into tree crowns. Such movement is discouraged if lower canopy layers are removed, interrupting the upward spread of fire.

The limited quantitative data on surface fuels at spotted owl sites (see tables in Chapter 5) suggest that loadings of large-diameter (greater than 11 inches) woody fuels are variable, but generally moderately heavy when compared to the range of loadings of natural fuels described by Blonski and Schramel (1981) for mixed-conifer forests in the Sierra Nevada. The guidelines in Chapter 1 for retention of at least 10-15 tons/acre of large downed wood represent the low end of the range of values observed in owl habitat-a loading probably acceptable from a fuels standpoint in most situations. Residues less than 11 inches in diameter probably are less essential to owls. Removal of smaller fuels, especially those less than 3 inches in diameter, results in reduced fire intensities, lower rates of spread, and lower resistance to control.

Fire and Fuels Management Options

Chapter 1 includes general guidelines for fuels management as part of its recommendations for interim management of "Other Forested Public Lands" in the Sierra Nevada. An alternative approach for interim management of *"Selected Timber Strata"* presented in Chapter 13 also includes guidelines for fuels management. In addition, Chapter 13 offers suggestions for fuels management as part of a set of potential long-term strategies to manage for owl habitat in Sierran mixed-conifer forests. Management activities described in Chapters 1 and 13 involve various kinds of cuttings. Because of the additional fuels created by these cuttings, and the warmer and drier microclimate at the forest floor resulting from stand openings, adequate treatment of slash fuels is essential. Otherwise, wildfire hazard is likely to be greater than before the activity (Countryman 1955, Weatherspoon and Skinner 1992). Several options are normally available to treat fuels, and revenues from harvested timber often will fund part or all of the planned fuels management.

In this section, we discuss a general approach for using prescribed burning to manage fuels (in addition to any other benefits that might accrue) in areas of nesting and roosting habitat where commercial harvesting of timber or other wood products will not be done. Such areas might include *"Protected Activity Centers"* (Chapter 1) and any other areas of owl habitat from which logging has been excluded administratively or legally. They might also include *"Selected Timber Strata"* in locations where harvesting is not economical for various reasons, given the constraints outlined in Chapter 1. Effects of prescribed burns should be carefully monitored as part of adaptive management experiments designed to improve our understanding of owl habitat and our ability to manage for it (Chapters 2 and 13).

Considering the significant and increasing risk of stand-destroying wildfire, as discussed earlier, we recommend that prescribed burning in these areas be given a high priority. Without substantial increases in funding for prescribed burning, the likelihood of losing large acreages of owl habitat to severe wildfires will increase over time. Additional prescribed burning would produce more smoke at a time when regulation of air quality is becoming increasingly restrictive. Consequently, the benefits of underburning-for owl habitat, for other ecosystem values, and for reducing smoke from wildfires-and associated tradeoffs in air quality will need to be clearly defined and articulated. This should be coupled with increased utilization of woody material and greater use of nonburning methods of fuels management in timber harvest areas, to the extent that they make sense ecologically and managerially. The prescribed burning recommended here should be coordinated, on a broad scale, with fuels management activities described in Chapters 1 and 13 to ensure the most effective and efficient use of dollars and other resources for protecting owl habitat. In many areas, succession and fuel accumulation have progressed to the point that prescribed burning is impractical as a first treatment. Outside *"Protected Activity Centers,"* such areas may require some combination of understory thinning and mechanical treatment of fuels, or removal prior to burning, to ensure that fire intensities remain within an acceptable range. We suggest the following priorities for prescribed burning within nonharvested areas of owl habitat in the Sierran mixed-conifer type.

First Priority

All hazard-reduction objectives of prescribed burning involve reducing amounts and continuity of fuels. Our recommended first priority is to isolate (that is, disrupt fuel continuity around) known nest and roost sites within *"Protected Activity Centers,"* using a band of prescribed bums. We recognize that this strategy poses some small risk to existing birds, but these risks can be at least partially mitigated. To the extent possible, burns should be concentrated, at least initially, on south-facing slopes (aspects from southeast through west) and ridges surrounding or adjoining nest/roost sites. Compared with more northerly slopes, these aspects have drier, more flammable fuels likely to support severe wildfires under a wider range of burning conditions (given effects of fire suppression). On the other hand, southerly slopes offer several advantages for prescribed burning: (1) They dry out earlier in the year, sometimes allowing spring burns to be done with minimal construction of firelines (thus lower cost) at times when fire will not spread onto adjacent northerly slopes. (2) Stands on south-facing slopes tend to be more open, with less dense understory to provide troublesome fuel ladders. (3) They tend to have a higher proportion of ponderosa pine, which not only resists fire damage rather well but also provides litter that can carry fire at the cool, moist end of a prescription-frequently desirable conditions for a first burn.

After many decades of fuel accumulation, initial prescribed burns can result in excessive consumption of duff and coarse woody debris. This is undesirable for at least two reasons: First, duff and coarse woody debris are important substrates for hypogeous fungi-prime food for flying squirrels (Chapters 4 and 10); and second, long-duration heating from extended smoldering of duff can damage tree roots and root crowns, sometimes causing delayed mortality even in large, old trees (Thomas and Agee 1986, Swezy and Agee 1991, Sackett pers. comm.). Conducting initial prescribed burns in the spring, when the moisture content of duff and large fuels is high, will help to minimize the problem of excessive duff consumption. The more flammable surface fuels-litter and small woody debris-can still be largely consumed. An additional advantage of low consumption of duff and large woody fuels is a reduction of atmospheric emissions. As adaptive management experiments continue over time, efforts should be made to align prescribed burns more closely with natural fire regimes in terms of the frequency and season of burns. In the meantime, however, effects of initial spring prescribed burns should be carefully monitored to assure that species diversity is retained and that birds and other wildlife are not disturbed during the breeding season.

In stands with many small understory trees and low crowns, burning should be initiated carefully, using small test burns at first. Flame lengths and their effect on torching of small trees should be closely monitored, and firing patterns should be adjusted as necessary to keep flame lengths within prescribed limits (Martin and Dell 1978, Kilgore and Curtis 1987, Weatherspoon et al. 1989). An initial prescribed burn will usually create some interruption of vertical fuel ladders (after scorched needles drop to the ground). Many small trees will be killed, however, and often more dead fuels will be created than consumed. Such understory burns, therefore, carry an implied commitment that the stand will be reburned at least once, generally within 10 years or so, to clean up fuels created by the first prescribed burn and to reduce vertical fuel ladders further.

Second Priority

After nest and roost sites have received some protection, a more general program of prescribed burning should be initiated. The objective is to break up fuel continuity on a larger scale and to begin to restore fire as a natural process in the ecosystem. Southerly slopes and ridgetops would be favored for burning, as suggested above. Followup burns would be implemented as needed to effect and maintain a meaningful interruption of fuel continuity and reduction in wildfire hazard. Burns should be well-distributed, creating a mosaic of broad "fuelbreaks" covering one-third or more of the total area. Such a program would be expected to limit substantially the size and severity of subsequent wildfires. Special emphasis should be given to prescribed burning that reinforces natural and constructed barriers to fire, such as rocky outcrops, bare ridges, roads, and constructed fuelbreaks. These provide relatively defensible areas from which firefighters can safely implement fire suppression strategies.

As indicated earlier, the approach discussed in this chapter assumes no commercial harvesting (including biomass harvesting of small trees). Outside *"Protected Activity Centers"* or similarly restrictive areas, however, initial prescribed burns in some stands with dense understories and dangerous fuel ladders may be facilitated by felling many of the small trees before burning. To limit intensity and consumption, and thus damage to the residual stand, the prescribed burn could then be done before the newly felled trees have fully dried.

Third Priority

For long-term protection, prescribed burning should be applied throughout owl habitat in the mixed-conifer zone with a frequency distribution similar to presettlement fire intervals. Northerly aspects and other areas not previously included in the prescribed burning program should be incorporated. Limitations on such a program and factors to consider include: (1) availability of resources; (2) need for improved information from research and monitoring activities concerning habitat attributes, fire history, and fire effects; (3) need for prescribed fire to maintain and improve owl habitat in the absence of other silvicultural tools; (4) need for fire to provide other ecosystem values; and (5) smoke management and air quality implications of a widespread prescribed burning program (including information about estimated background levels of smoke during presettlement fire regimes, and tradeoffs between increased smoke from prescribed fires versus reduced smoke from wildfires). If the second priority program is carried out successfully-coupled with appropriate fuels management in adjoining harvested areas (Chapters 1 and 13)---occurrence of large, catastrophic wildfires within owl habitat will be of less concern. The focus of prescribed fire for this third stage will then shift generally from hazard reduction to reestablishment of an important ecosystem process. Long-term sustainability of owl habitat on a landscape scale should result.

Red Fir

Fire Regimes

The relatively few studies of natural fire regimes in the red fir type have indicated mean fire intervals ranging between about 40 and 100 years (Kilgore 1981, Pitcher 1987, Taylor and Halpern 1991). Higher-elevation areas tend to have less frequent fires because biomass (fuel) accumulates more slowly and weather conditions that will support a fire occur less often. Despite longer fire intervals than in the mixed-conifer type, fire has been the dominant disturbance factor associated with episodes of regeneration in much of the red fir type. A range of severities and frequencies of fire has led to a complex pattern of various patch sizes and tree ages (Pitcher 1987, Taylor and Halpern 1991). Compared with lower-elevation forest types, fire suppression has had less effect on the red fir type. Suppression activities began later in red fir forests, and fewer fires would have burned there even without suppression. In addition, because red fir forests are largely monospecific and red fir is relatively shade tolerant, the successional trend toward more shade-tolerant species in the absence of fire (a concern in the mixed-conifer type) is not a factor in the red fir type.

Despite many lightning-caused ignitions in the red fir type (Maupin pers. comm.), such fires seldom have gotten large on lands where a suppression strategy is used, because initial attack is almost always successful. The behavior of natural fire has been extensively documented in Yosemite and Sequoia/Kings Canyon NPs, where much of the red fir type is included in the prescribed natural fire zone. To date, no evidence suggests that the prescribed natural fire programs in the NPs have had an adverse impact on the owls found there. Lightning fires in the red fir type usually burn with relatively low intensity and spread slowly over long periods, with occasional episodes of rapid spread during periods of severe fire weather. Crown fire is unusual in this type except under rare high-wind events, partly because sparse understory vegetation (Rundel el al. 1977) provides limited fuel ladders. Some examples of crown fire, however, were observed during the 1987 fire season. Torching also has been observed when human-caused fires burned into the red fir forest under extreme conditions.

Sixteen percent of the fires recorded in Yosemite NP between 1930 and 1983 occurred in the red fir zone, even though it comprises only 8 percent of the park. The majority of those fires were single trees, although larger fires occurred when red fir was mixed with chaparral (van Wagtendonk 1986).

Fuels

Color photo 5-1 provides an excellent illustration of typical fuel conditions in red fir. Fuel bed characteristics are quite different from those in the other habitat types. The short needles form a dense litter layer, which is further compacted by a heavy snow pack. This litter burns slowly, with relatively low intensities. Fuel ladders are nearly always interrupted. Dead-and-downed fuel loadings may be heavy in older stands, but fuel moistures remain high during most years in these high-elevation stands.

Fire Management Options

Fire may be allowed to play its natural role in much of the red fir type. Large sections of red fir forest found in wilderness areas should be evaluated for inclusion in wilderness fire-management programs that emphasize the role of fire as a natural process.

Southern California Mixed-Conifer

Fire Regimes

The natural role of fire in the southern California mixed-conifer community is similar to that described for the Sierran mixed-conifer community. Studies of fire history in the Los Padres NF (Talley and Griffin 1980) and the San Bernardino Mountains (McBride and Laven 1976, McBride and Jacobs 1980) suggest slightly longer mean fire intervals in these forests than those found in the Sierra Nevada. This may be explained by the lower incidence of lightning storms there, as well as smaller contiguous areas of mixed-conifer vegetation. In the southern California mixed-conifer type, as in the Sierra Nevada, the early fire regime was typified by frequent low- to moderate-severity fires, which burned over long periods under a variety of fuel and weather conditions (Minnich 1988).

Fire suppression has been effective in reducing the number of large fires in the mixed-conifer type in the mountains of southern California. An analysis of fire records by McBride and Laven (1976) indicated that fire suppression has been effective in sharply reducing the number of acres burned on the San Bernardino NF, for example, from an annual acreage of 5,890 acres during the 1940s to 3,774 acres during the 1960s.

Talley and Griffin (1980) found evidence that twentieth century fire regimes result in infrequent fires of an intensity causing widespread mortality in pine stands that survived the frequent low- to moderate-severity fires of the past. Coniferous forests, which once burned more frequently than the chaparral stands below them, now burn at a frequency similar to that in the chaparral.

Examination of fire records indicates that most large wildfires in mixed-conifer forests in southern California fall under Scenarios 1 and 3, described for the Sierran mixed-conifer type.

Fire Management Options

Current practices of protecting all pairs of owls in this type should be continued. The fire management options described for Sierran mixed-conifer forests apply in southern California as well. It is essential, however, that fuels also be managed in the chaparral communities surrounding the conifers, to avoid catastrophic wildfires that spread from below into the mixed-conifer zone.

Live Oak/Bigcone Douglas-Fir Forests

The live oak/bigcone Douglas-fir community provides habitat for an estimated 41 percent of owl sites in southern California (tables 1B and 3I). Within the lower portions of its elevational range, this community occurs near streams in moist, shaded canyons and draws, where aspects are mostly north and east. As elevation increases, it occurs on other aspects and is less restricted to canyons (McDonald and Littrell 1976). Typically, bigcone Douglas-fir comprises a scattered overstory of single trees or small groups of trees, and tree-sized canyon live oaks form a relatively continuous midstory canopy. Shrubs and herbaceous plants are largely absent in the understory except beneath openings and along the margins of stands (McDonald 1990). Stands of live oak/bigcone Douglas-fir usually intergrade with chaparral along their margins.

Fire Regimes and Fire Effects

McDonald and Littrell (1976, p. 319) described "the overall pattern of the bigcone Douglas-fir-canyon live oak community [as] that of a stable, self-perpetuating, somewhat exclusive community, with tendencies toward the climax or even postclimax successional stage." The community evidently is not well-adapted to frequent fires. Bigcone Douglas-fir is unusual among conifers in its ability to sprout from a fire-scorched crown (color photo 5-39), but it is weakened from repeated fires that deplete energy reserves (McDonald 1990). It does not survive "torching" of the crown (consumption of foliage by flames). Seeds contained in cones in torched crowns almost certainly would not survive to provide regeneration. Indeed, natural regeneration of the species is very slow following severe fires (Minnich 1980). Young bigcone Douglas-firs are moderately shade-tolerant, and establishment of natural regeneration is often most successful in the partial shade provided by the canyon live oak canopy (McDonald 1990). Young trees grow slowly in the understory, however, and are easily destroyed by surface fires.

Oaks in general are not noted for their resistance to fire damage. Even among oaks, however, canyon live oak is unusually sensitive to damage and top-kill by fire (Minnich 1980, Plumb 1980). Its thin, dry, flaky bark ignites easily, often carrying fire several feet up a bole and commonly burning completely through the bark to expose the underlying wood. Frequently, heat kills enough cambium to girdle the bole, even with low-intensity surface fires (Plumb 1980). The relatively closed, compact canopy architecture also tends to trap heat from a fire beneath the canopy, thereby increasing crown scorch. On the other hand, canyon live oak sprouts vigorously from the root crown following top-kill by fire, and frequently after sublethal damage as well.

The unusual susceptibility of canyon live oak to top-kill by fire suggests that stands with many large, old trees (seemingly high-quality owl habitat-Chapter 5) probably have not experienced fires of any significance for many decades (Minnich 1988). The species grows more quickly to tree size in more mesic habitats, where fire intervals also are generally longer. Canyon live oaks that escape burning long enough to attain tree stature, in turn, tend to bestow a fire-retardant quality on the stands in which they grow (Minnich 1980). Possible reasons include: (1) chaparral shrubs or other understory plants that might provide a flammable fuel ladder into tree crowns are virtually absent; and (2) litter tends to be meager beneath canyon live oak and it is not particularly flammable, perhaps in part because of dry ravel on steep slopes that promotes mixing of litter and soil. Minnich (1977, p. 447) described fires spreading from chaparral into live oak/bigcone Douglas-fir stands that "usually incinerated the outermost fringe of stands. With further progress into the grove, the pattern of total combustion graded into a hot surface fire which only scorches the oaks as the distance between the tree canopy and ground fuels increases." Where wind and other burning conditions sustain a crown fire through the stand, however, restoration of prefire stand conditions will likely take a long time. Without intervention, canyon live oak sprouts will come up in a sea of seedling chaparral shrubs. For many decades, the new community will be more likely to reburn than the old one-until the oaks again attain tree stature and shade out the shrubs. Meanwhile, bigcone Douglas-fir probably will be very slow to return, particularly if no surviving seed trees are nearby.

Fire and Fuels Management Options

We do not recommend prescribed burning within live oak/ bigcone Douglas-fir stands (see Plumb 1980). From the standpoint of wildfire hazard, these stands are relatively nonflammable, as described earlier. They probably will not support a stand-destroying crown fire except under extreme conditions in which prescribed burning or other surface fuel reduction will have made little difference in fire behavior. Under less extreme conditions, the stand probably will support a moderately intense surface fire, which would top-kill many or most of the live oaks and allow many of the bigcone Douglas-firs to crown sprout. Restoration of suitable owl habitat would take place sooner than after a crown fire. If prescribed burning were done, it would be difficult and expensive in many stands because of the steep, broken terrain. Moreover, given the discontinuous, low-flammability fuels occurring in many stands, moderately severe burning conditions probably would be required to carry fire and reduce fuels significantly, and those conditions might produce levels of damage to canyon live oaks approaching those that prescribed burning was intended to prevent. To the extent that the canopy is opened by top-kill of oaks during prescribed burning, chaparral shrubs probably would invade the stand, making it more likely to burn severely in the future.

If the decision is to use prescribed burning, it should be concentrated on gentler slopes where access is easier, fuels are more continuous, and probable damage from wildfires is greater. Minnich (1980) observed 37 percent survival of bigcone Douglas-fir following wildfires on slopes less than 20 degrees, but more than 90 percent survival on slopes greater than 40 degrees.

A better fuels management strategy to protect live oak/ bigcone Douglas-fir stands may be to concentrate prescribed burning in chaparral near these stands. Highest priority should be given to the more flammable chaparral types and to more decadent chaparral with higher dead-to-live fuel ratios, which would support more intense wildfires and thus be more likely to carry a crown fire into adjacent trees. Similarly, higher priority should be given to chaparral near live oak/bigcone Douglas-fir stands with more continuous surface fuels and those on gentle to moderate slopes (as opposed to very steep, broken slopes and canyons). Movement of fire into live oak/bigcone Douglas-fir should be minimal if prescribed burns are planned for relatively moderate burning conditions (which should be suitable for burning decadent chaparral or relatively flammable chaparral species) and in such a way that slope and wind direction favor movement of the fire away from the live oak/bigcone Douglas-fir stand. Prescribed burning of decadent chaparral should improve owl foraging habitat because of increased production of woodrats (more succulent and nutritious foliage in the new growth) and improved access to woodrats (see Chapter 10).

In the event of a severe wildfire in live oak/bigcone Douglas-fir, active measures should be taken to restore owl habitat. Because prospects are poor for natural regeneration of bigcone Douglas-fir, nursery-grown seedlings should be planted as soon as possible. Competing shrubs and other vegetation should be controlled adequately to ensure survival and rapid early growth of the bigcone Douglas-fir seedlings. Some thinning of sprouting clumps of canyon live oaks might speed their return to tree size.

Southern California Riparian/ Hardwood

Accumulations of dead-and-downed woody fuels are generally low in this type. Fire behavior depends on understory composition, which can be variable (color photos 5-29 to 5-32, 5-45 to 5-47). Areas with a grass understory burn rapidly with low to moderate intensities. Effects are generally benign. Stands with a shrub understory show great variability in fire behavior and effects, depending on species composition and abundance of shrubs. These stands should be examined on a case-by-case basis, because they are of great importance, relatively limited in acreage, and vary in their vulnerability to wildfire. Management should focus on maintaining a closed canopy of trees. In some stands, prescribed burning or other fuels treatment may be needed to prevent overstory mortality from wildfire. Fire also may be necessary in some situations to regenerate overstory trees, such as oaks.

Considerations for Fire Suppression in Spotted Owl Habitat

The wildland fire agencies have demonstrated the efficacy of initial attack in excluding wildland fire from some types of spotted owl habitat (Sierran mixed-conifer, red fir, and southern California mixed-conifer). Such suppression efforts are essential to prevent large, severe wildfires, while concurrently making efforts to condition stands to reduce wildfire hazard. Continued success depends on maintaining sufficient initial attack resources to protect the habitat. Wiitala (1991) proposed a way to quantify the risk of experiencing unacceptable fire events in areas that are highly valued, but for which we have no method of assigning a monetary value for input into the loss portion of cost-plus-loss equations. A similar analysis should be developed for California owl habitat, to justify the initial attack organization needed for its protection.

A consideration in suppression of wildfire in high-value areas is the trade-off between efficient suppression that minimizes the fire size and the damage that can result from aggressive suppression action. The concept of appropriate suppression response has been articulated by Mohr (1989) and Mohr and Moody (1991), emphasizing techniques that effectively and efficiently suppress fires while minimizing direct impacts.

Selecting suppression strategies at initial attack, extended attack, and project fire level also requires weighing the advantages of backing off to the exterior of high-value areas to minimize suppression impacts, against the amount of damage that the fire is expected to cause within the selected perimeter. The fire manager has considerable latitude in selecting a strategy, ranging from aggressive control to confinement. Selection of suppression alternatives should be based on projected or observed fire behavior to predict fire effects. This analysis will be fire-specific because of variation in such factors as fuel loading, fuel moisture, weather, and topography. Interaction among wildlife biologists or resource advisors, fire behavior analysts, and operations personnel is essential to develop a balanced display of the suppression costs and resource damage of alternatives. Successful implementation requires preplanning by fire managers in consultation with biologists.

Fire suppression must be done in a manner that reflects a high regard for public and firefighter safety. The following additional factors should be considered when managing wildfires that start in or threaten spotted owl habitat:

1. The degree of involvement of canopy layers, based on the intensity of surface fire and the amount of torching predicted in each canopy layer.

2. The expected amount of consumption in litter and duff layers.

3. The relative patchiness of the burn, and the percent of various fire intensities projected within the fire perimeter.

4. The expected amount of downed-log volume to be consumed, especially logs greater than 9 inches in diameter. This evaluation should include both rotten and sound logs.

5. Location of the fire relative to known nest sites.

6. Timing of the event relative to the owl's breeding season.

7. The quantity and quality of habitat in the area of the fire. If the fire is burning in an area where suitable owl habitat is rare, greater effort would be taken to minimize habitat destruction by the fire.

8. Expected impact on the owl's prey base.

Conclusions

Fire has been a dominant force in shaping the forested ecosystems that provide habitat for the California spotted owl. The various habitat types used by the owl differ in terms of (1) the influence of historical fire regimes on their structure, composition, and function; (2) the extent to which the habitat types have been altered by human activities since European settlement; and (3) the risk of substantial habitat loss by severe wildfires. In this chapter we have summarized fire management considerations relating to protection and possible enhancement of owl habitat, with emphasis on the Sierran mixed-conifer and the live oak/bigcone Douglas-fir forest types.

The Sierran mixed-conifer type is the State's most important and extensive habitat type for the California spotted owl. Human activities since the mid-1800s-especially sheep grazing, fire suppression, and "selective" cutting-have profoundly affected the structure and composition of these forests. Changes include a marked increase in the density of shade-tolerant understory trees. The vertical fuel ladders thereby created, along with substantial increases in surface fuels, have greatly increased the potential for stand-replacing crown fires. Severe wildfire in Sierran mixed-conifer forests may represent the greatest threat to current owl habitat.

The wildland fire agencies must maintain an effective suppression organization to minimize the damage from such fires. Problems resulting from many decades of over-zealous suppression cannot be resolved overnight by allowing wildfires to run their course in highly hazardous fuel complexes. Concurrently, however, managers must pursue aggressive, environmentally sound fuels management programs to reduce wildfire hazard in and around owl habitat. As described in this chapter, prescribed fire has an important role to play in reducing hazard and enhancing a variety of ecosystem values associated with the natural functioning of fire. In addition, fuels management methods (including but not limited to prescribed fire) should be considered integral components of silvicultural approaches to managing owl habitat, such as those discussed in Chapters 1 and 13.

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